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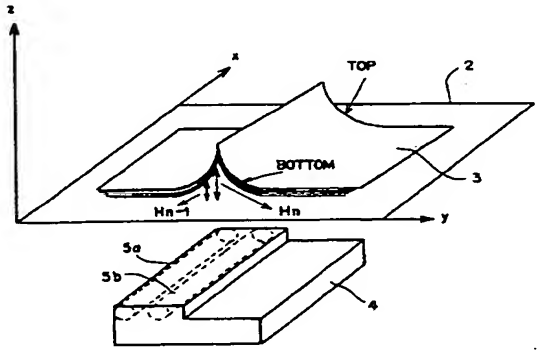
(54) Method and apparatus for correcting degradation of book center image by image processing based on contour of book center image

(57) An image processing apparatus corrects degradation of an image of a pair of spread pages of a bound book placed on a document table. The image processing apparatus includes a height obtaining unit which obtains a plurality of heights, above the document table, of a plurality of points of the pair of spread pages, based on a contour of the pair of spread pages which appears in the image, and an image correcting unit which corrects the degradation of the image based on the plurality of heights obtained by the height obtaining unit. The degradation may be unevenness of lightness, deformation, a blur, or the like.

F I G . 1



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spread pages of a bound book as an original document, based on a contour of the pair of spread pages which appears in an image of the pair of spread pages, where the bound book is placed on the document table; and (b) correcting degradation of the image of the pair of spread pages, based on the plurality of heights obtained by the height obtaining unit.

[0010] According to the second aspect of the present invention, there is provided an image processing apparatus which contains a height obtaining unit which obtains a plurality of heights, above a document table, of a plurality of points of a pair of spread pages of a bound book as an original document, based on a contour of the pair of spread pages which appears in an image of the pair of spread pages, where the bound book is placed on the document table; and an image correcting unit which corrects degradation of the image of the pair of spread pages, based on the plurality of heights obtained by the height obtaining unit.

[0011] With the image processing apparatus according to the second aspect of the present invention, the heights of a plurality of points of the book center are obtained based on the contour of the book center in the image obtained by scanning the book center, and degradation of the image is corrected based on the heights obtained from the contour of the book center in the image. That is, the degradation of the image can be corrected based on only the image. Therefore, it is unnecessary to provide any specific sensor or additional device, or to change the construction of the conventional scanner. Thus, the degradation of the image can be corrected at low cost.

[0012] In the image processing apparatus according to the second aspect of the present invention, the above height obtaining unit may contain a reference line extracting unit which extracts at least one reference line based on a top and bottom portions of the contour of the pair of spread pages which appears in the image; a correction area determining unit which determines as a correction area an area of the image corresponding to a portion of the pair of spread pages which is lifted from the document table, based on the at least one reference line and the contour; a distance obtaining unit which obtains a distance from each pixel of a portion of the contour in at least one edge of the correction area, to the at least one reference line; an edge height obtaining unit which obtains a height of each point of a top and bottom edges of the portion of the pair of spread pages above the document table, based on the distance obtained by the distance obtaining unit; and a height distribution obtaining unit which obtains a height of each point of the portion of the pair of spread pages above the document table, based on the height of each point of the top and bottom edges of the portion of the pair of spread pages.

[0013] That is, the height of each point of the edges of the book center is obtained based on the top and bottom portions of the contour of the book center which appears in the image, and the height of each point of the book center can be obtained based on the height of each point of the edges of the book center.

[0014] In the above height obtaining unit, the at least one reference line is a straight line obtained by extending an undeformed straight portion of the contour of the pair of spread pages which appears in the image.

[0015] The height of each point of the edges of the book center can be obtained even if the spread pages in the pair are differently skewed.

[0016] When the skew angles of the spread pages in the pair are identical, it is possible to obtain the distance from each pixel of a portion of the contour in at least one edge of the correction area to only one reference line. However, when obtaining the distance based on only one reference line, it is necessary to provide a means to equalize the skew angles of the spread pages in the pair. The skew angles of the spread pages on the document table are generally different, and the skew angles are often different even between the top and bottom edges of each of the spread pages. Therefore, when the above means for equalizing the skew angles of the spread pages is not provided, it is preferable to obtain reference lines (four in total) from the top and bottom edges of the respective spread pages in the pair, to accurately obtain the heights of the respective points of the book center above the document table.

[0017] The correction area may be defined as an area encircled by the top and bottom portions of the contour of the spread pages and lines connecting top and bottom branch points of the respective spread pages, where the top and bottom branch points are points at which the corresponding reference lines branch from the top and bottom portions of the contour, respectively. In other words, the branch points are points at which the correction is commenced.

[0018] The height of each point of the edges of the book center can be obtained even if the book is placed on the document table in a slanting direction. However, when the image of the bound book is read by a line sensor, the book must be placed on the document table so that the directions of the top and bottom edges of the book are not parallel to the direction of the line sensor. Otherwise, when the image of the bound book is read by an area sensor, there is no requirement regarding the direction of the book on the document table.

[0019] In the image processing apparatus according to the second aspect of the present invention, the above image correcting unit may be a unit which corrects unevenness of lightness, deformation, or a blur of the image.

[0020] When the image correcting unit in the second aspect of the present invention corrects unevenness of lightness, the image correcting unit calculates, based on the heights of the respective points of the book center, corrected values of lightness for the respective pixels of the book center portion of the image, where the corrected values of lightness are values of lightness which the respective pixels of the book center portion of the image will have if the book center of the spread pages is in contact with the document table. Then, the image correcting unit changes the values of lightness which the respective pixels of the book center portion of the image, to the corrected values of lightness.

table, and corrects deformation, unevenness of lightness, and a blur of an image of the bound book, based on the distance.

[0027] Fig. 3 is a block diagram illustrating the construction of the image processing apparatus as the embodiment of the present invention. As illustrated in Fig. 3, the image processing apparatus 100 as the embodiment of the present invention contains an analyzing unit 106 including a reference line extracting unit 101, a correction area determining unit 102, a distance calculation unit 103, an edge height calculation unit 104 and a height distribution calculation unit 105. A lightness correction unit 107, a deformation correction unit 108 and a blur correction unit 109 are connected to the height distribution calculation unit 105. The lightness correction unit 107, the deformation correction unit 108 and the blur correction unit 109 are connected to a correction selecting unit 110, which is connected with a trimming unit 111 that is connected to a skew correction unit 112.

[0028] The analyzing unit 106 corresponds to the aforementioned height obtaining unit in the image processing apparatus according to the second aspect of the present invention. The analyzing unit 106 contains the reference line extracting unit 101, the correction area determining unit 102, the distance calculation unit 103, the edge height calculation unit 104, and the height distribution calculation unit 105, which correspond to the reference line extracting unit, the correction area determining unit, the distance obtaining unit, the edge height obtaining unit, and the height distribution obtaining unit, respectively. That is, the analyzing unit 106 obtains a plurality of heights, above the document table, of a plurality of points of the pair of spread pages of the bound book, based on a contour of the pair of spread pages which appears in the image of the book.

[0029] Based on the height (distance) of each point of the book center portion above the document table, the lightness correction unit 107 corrects unevenness of lightness in the image of the book, the deformation correction unit 108 corrects deformation of the image, and the blur correction unit 109 corrects a blur in the image. The correction selecting unit 110 performs necessary correction of degradation of the image by selectively using the lightness correction unit 107, the deformation correction unit 108, and the blur correction unit 109. The trimming unit 111 trims off unnecessary portions of the image. The skew correction unit 112 corrects the skew of the image.

[0030] Explanations of the respective elements in the construction of Fig. 3 are provided below.

[1] First, explanations on the reference line extracting unit 101 are provided below.

Fig. 1 shows a scene of scanning of a bound book by a flat bed scanner. In Fig. 1, the bound book 3 is placed on a document table 2 of the flat bed scanner as an image reading apparatus 4. In Fig. 1, the main scanning direction, the sub-scanning direction, and the direction of the lift from the document table 2 are indicated by x, y, and z coordinates, respectively. Considering the aforementioned case in which the skew angles of the top and bottom portions of the contour of the pair of spread pages are different, four reference lines 11, 12, 13, and 14 (as illustrated in Fig. 4) are extracted by the reference line extracting unit 101 in this embodiment.

The image reading apparatus 4 contains a reduction optical system, and obtains density of each pixel of the image of the pair of spread pages in the form of digital value of n bits (e.g. 8 bits). In this embodiment, the digital value 255 corresponds to the pure white level, and the digital value 0 corresponds to the pure black level. Since, as illustrated in Fig. 2, the density of each point of the book center portion increases with the lift of the point, the digital value representing the density of each point of the book center portion decreases with the lift of the point.

When an average density value in areas of the above image corresponding to portions of the spread pages which are in contact with the document table 2 is obtained, and the entire image is binarized based on the average density value, the binarized image as illustrated in Fig. 4 is obtained. In the binarized image of Fig. 4, the areas 91 corresponding to the portions of the spread pages which are in contact with the document table 2 are white, and all of the other areas are black. Next, almost straight portions of the top and bottom sides of the contours the areas 91 are respectively extended to obtain four straight lines as the aforementioned four reference lines 11 to 14. In order to determine the straight lines, any known technique for detecting a straight line, such as the Hough transformation, boundary tracing, and the method of least squares, may be used.

[2] Explanations on the correction area determining unit 102 are provided below.

Fig. 5 is a diagram illustrating an example of a contour image of a pair of spread pages of a bound book placed on a document table. Since a book center portion of a scanned image such as the image of Fig. 2 is darker than the aforementioned portions of the spread pages which are in contact with the document table 2, it is impossible to extract contours of the book center portion of the spread pages from the binarized image such as the image of Fig. 4. Therefore, the contour image of Fig. 5 is obtained by averaging the book center portion of a scanned image such as the image of Fig. 2, and then binarizing the averaged image. Thus, the contours of the book center portion of the spread pages can be extracted as illustrated in Fig. 5.

In Fig. 5, the points 21, 22, 23, and 24, at which the reference lines 11, 12, 13, and 14 branch from the top and bottom portions of the contour of the spread pages, are hereinafter called correction start points. Then, an area encircled by a straight line connecting the correction start points 21 and 23, a straight line connecting the correction start points 22 and 24, a portion of the contour of the spread pages between the correction start points 21 and 22,

coordinates of the points p_{an} and p_{in}.

Furthermore, the accurate value of H_{in}' can be obtained by the following equation (2)'

$$Hin' = Han + (Hbn - Han) \times \frac{\sqrt{xi^2 + yi^2}}{\sqrt{xj^2 + yj^2}} \quad (2)'$$

where y_j is the difference between the y coordinates of the points p_{an} and P_{bn}, and y_i is the difference between the y coordinates of the points p_{an} and p_{in}.

Thus, the analyzing unit 106 obtains a plurality of heights, above the document table, of a plurality of points of the pair of spread pages of the bound book, based on the contour of the pair of spread pages which appears in the image of the book.

[6] Explanations on the lightness correction unit 107 are provided below.

Fig. 9 is a side view illustrating a geometrical relationship among the spread pages of the book document 3, the document table 2, light sources 5a and 5b, a mirror 8, and a charge coupled device (CCD) 9 in the flat bed scanner. In the configuration of Fig. 9, the surfaces of the spread pages of the book document 3 are illuminated by light from the light sources 5a and 5b, and the light reflected by the point B on the surfaces of the spread pages of the book document 3 is lead through the point A on the document table 2 and is reflected by the mirror 8 to the charge coupled device (CCD) 9. In order to obtain a value of corrected lightness at the point A, intensities of the incident light and the reflection light at the points A and B are necessary, and can be obtained as follows.

The intensities of the incident light at the points A and B are inversely proportional to the identical distance from the light sources 5a and 5b to the points A and B, respectively.

That is, the intensity I_A of the incident light at the points A is expressed as

$$I_A \propto 1/\sqrt{(f1/n + f2)^2 + r^2} \quad (3)$$

and the intensity I_B of the incident light at the points B is expressed as

$$I_B \propto 1/\sqrt{(f1/n + f2 + H)^2 + r^2} \quad (4)$$

where f1 is the thickness of the document table 2, f2 is the distance from the centers of the light sources 5a and 5b to the document table 2, n is the refraction index of the glass of the document table 2, r is the distance from the centers of the light sources 5a and 5b to the midpoint p between the centers of the light sources 5a and 5b, and H is the distance from the point B to the document table 2.

The intensities of the reflection light at the points A and B can be obtained by the following equations (5) and (6), respectively.

That is, the intensity R_A of the reflection light at the points A is expressed as

$$R_A = I_A \times \rho \times 2\cos\theta, \quad (5)$$

and the intensity R_B of the reflection light at the points B is expressed as

$$R_B = I_B \times \rho \times (\cos\psi 1 + \cos\psi 2), \quad (6)$$

where ρ is the reflectance of the paper of the book document 3, θ is the angle at the point A between the incident light from the light source 5a and the reflection light, $\psi 1$ is the angle at the point B between the incident light from the light source 5a and the normal to the surface, and $\psi 2$ is the angle at the point B between the incident light from the light source 5b and the normal to the surface.

As illustrated in Fig. 9, $\cos\theta$ is determined according to the positions of the light sources 5a and 5b, and can be obtained by the following equation (7).

$$\cos\theta = (f1 + f2)/\sqrt{\{r^2 + (f1 + f2)^2\}} \quad (7)$$

In addition, as illustrated in Fig. 9, $\psi 1$ and $\psi 2$ are expressed as

$$\psi 1 = \alpha + \Phi, \quad (8)$$

$$D_A = D_B \times 2 \times \cos\theta / (\cos\psi 1 + \cos\psi 2)$$

$$\times (a+H)^2 / a^2 \times \frac{\sqrt{\left(f1/n + f2 + H\right)^2 + r^2}}{\sqrt{\left(f1/n + f2\right)^2 + r^2}} \qquad (17)$$

Therefore, the lightness at the point A can be obtained by substituting the aforementioned height H_n or H_{in}' for H in the equation (17). Thus, the lightness at the point B can be corrected to the lightness at the point A.

[7] Explanations on the blur correction unit 109 are provided below.

The blur in the book center image is caused by the lift of the book center portion of the spread pages from the document table 2. That is, due to the lift of the book center portion, the book center portion is located beyond the depth of field of the reduction optical system, and therefore a blur occurs. The degrees of blurs at the respective points of the book center image are different according to the lifts of the corresponding points of the book center portion of the spread pages. Therefore, the blur correction unit 109 corrects the blurs of the book center image by varying the amount of correction according to the degrees of the blurs.

The degree of a blur is proportional to the height of each point of the book center portion. Therefore, image correction processing is performed by using a Laplacean operator so that the amount of correction varies with the of high frequency enhancement processing using a digital Laplacean operator. In the equation (18), f(i,j) indicates an image before correction, and g(i,j) indicates an image after correction.

$$g(i,j) = f(i,j) - \nabla^2 f(i,j) \qquad (18)$$

However, in this embodiment, a function of high frequency enhancement processing as expressed in the following equation (19) is used, where the digital Laplacean operator is weighted.

$$g(i,j) = f(i,j) - \gamma(H) \times \nabla^2 f(i,j) \qquad (19)$$

The weight $\gamma(H)$ in the equation (19) is a function which is proportional to the height H. Therefore, when the height H increases, the weight γ also increases.

Thus, when substituting the aforementioned height H_n or H_{in}' for H in the equation (19), correction of the blur can be performed so that the amount of the correction varies with the height H.

[8] Explanations on the deformation correction unit 108 are provided below.

The image correcting unit 108 obtains, by calculation based on the heights of the plurality of points of the book center portion, corrected pixel positions for the respective pixels of the book center portion of the image obtained by scanning the book document 3 placed on the document table 2, where the corrected pixel positions are imaginary pixel positions at which the respective points of the book center of the spread pages will be located if the book center portion of the spread pages is in contact with the document table 2. Then, the image correcting unit 108 moves the respective pixels of the book center portion of the image to the corrected pixel positions, and interpolated values are assigned to pixels which are vacated by the movement to the corrected pixel positions. Fig. 11 shows an example of a lift of the book center portion of the spread pages of the book document 3, and the movements of the respective points of the book center portion to the corrected positions on the document table 2.

First, explanations on correction of deformation in edges of the correction area corresponding to the edges of the book center portion are provided below.

It is assumed that, in the correction of deformation, a plurality of points r_n (n=1, 2, ...) on one of the edges of the book center move to a plurality of corrected points q_n (n=1, 2, ...) on one of the reference lines. The heights H_n of the plurality of points r_n (n=1, 2, ...) can be obtained by the equation (1) based on the respective distances L_n (n=1, 2, ...) from the reference line to a plurality of points of the contour corresponding to the plurality of points r_n (n=1, 2, ...).

The corrected point q_n on the reference line is determined as follows. Fig. 12 is provided for explaining a way of determining the corrected point q_n on the reference line. In Fig. 12, the y' axis corresponds to the reference line.

As illustrated in Fig. 12, the y' coordinate of the corrected point q_n is determined by obtaining the correction amount k in the y' direction, i.e., in the direction of the reference line. In order to obtain the correction amount k, first,

First, an unvacated pixel near the vacated pixel p_m is searched for in the direction of the reference line 11. When the unvacated pixel is searched for in the direction in which the y' coordinate increases, the unvacated pixel p_2 is found. On the other hand, when the unvacated pixel is searched for in the direction in which the y' coordinate decreases, the unvacated pixel p_1 is found. When it is assumed that the densities of the unvacated pixels p_1 and p_2 are respectively d1 and d2, the distance from the pixel p_m to the pixel p_1 is v1, and the distance from the pixel p_m to the pixel P_2 is w1, the density value to be assigned to the pixel p_m is determined by the following equation (24).

$$dm=d1\times w1/(v1+w1)+d2\times v1/(v1+w1) \quad (24)$$

When the deformation of the image is corrected as above, the image of the book center portion is extended. Therefore, in order to prevent overlap of the extended images of the spread pages, the extended images of the spread pages are relatively moved in the sub-scanning (y) direction. The amount of the relative movement of the extended images of the spread pages in the y direction is obtained based on the maximum amount of the movement of the pixels in the operation of correcting the deformation, i.e., the amount of movement of the book center points 31 and 32.

[9] Explanations on the trimming unit 111 are provided below.

The trimming unit 111 detects and trims off the fore edge portions of the image of the book document 3. Fig. 15 shows the fore edge portions of the image of the book document 3. The trimming unit 111 trims off the fore edge portions by extracting only an image of an innermost pair of pages (corresponding to the spread pages) in the image of the book document 3, as explained below.

First, the image of the fore edge portions is binarized by using the high frequency enhancement processing. Then, the binarized image is divided into a plurality of areas, and it is determined whether or not a straight line exists in each of the plurality of areas. Since edges of the respective pages of the book document appear as a straight line in some areas which overlap the fore edge portions, the trimming unit 111 recognizes that the image of the desired pair of spread pages extends inside the innermost areas in which a straight line appears, and extracts only a region inside the innermost areas as the image of the desired pair of spread pages. In order to detect a straight line, the Hough transformation, boundary tracing, the method of least squares, or the like may be used

[10] Other matters

The book document 3 may be placed on the document table 2 in a slanting direction. Therefore, the image of the book document 3 may be skewed. Further, skew angles of the right and left pages may be different. In such cases, the appearance of an output image is deteriorated. Therefore, skew correction processing is performed by the skew correction unit 112. Even if the skew angles of the right and left pages are different, the skew correction unit 112 can obtain the skew angles based on the reference lines 11 to 14. The skew of the image of each page can be independently corrected by rotation processing such as the Affine transformation.

[0031] As described above, in the above embodiment, correction of degradation of an image can be performed by only image processing, where the image is an image of a pair of spread pages of a book document 3 placed on a document table 2, and obtained by an image reading device having a reduction optical system. The degradation of the image may include unevenness of lightness, deformation, a blur, or the like, and occurs in a book center image. The correction is performed by only image processing, based on heights H_n or H_{in}' of a plurality of points of the book center image.

[0032] Although, in the described embodiment, the operation of detecting the heights of the respective points of the book center portion is incorporated in the operation of correcting the degradation of the image, the operation of obtaining the heights per se can be used separately.

[0033] All of the contents of the Japanese Patent Application No. 11(1999)-44965 are incorporated into this specification by reference.

Claims

1. An image processing apparatus comprising:

a height obtaining unit which obtains a plurality of heights, above a document table, of a plurality of points of a pair of spread pages of a bound book as an original document, based on a contour of the pair of spread pages which appears in a scanned image of the pair of spread pages, where the bound book is placed on the document table; and

an image correcting unit which corrects degradation of the image of the pair of spread pages, based on the plu-

FIG. 1

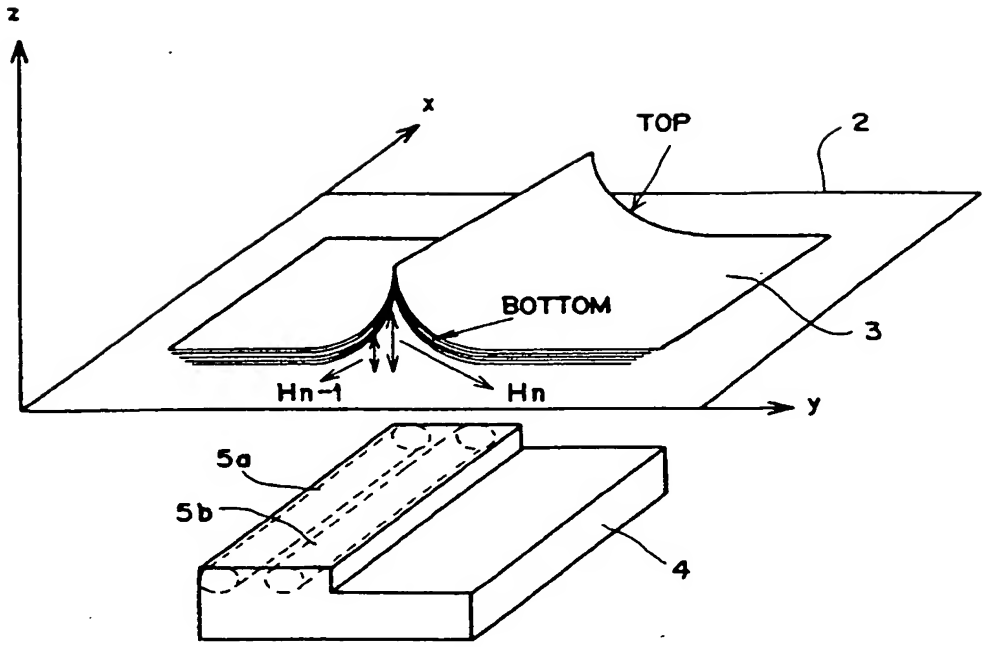

FIG.3

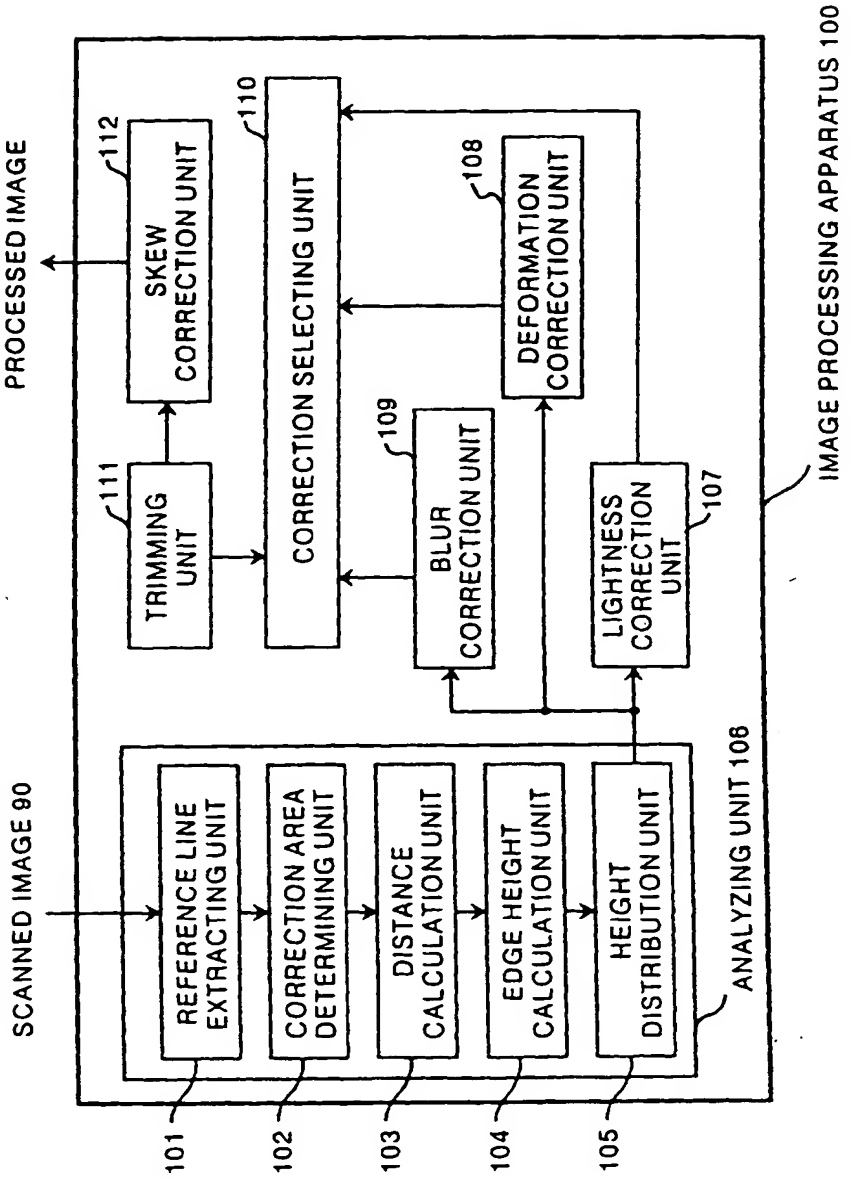

FIG.6a

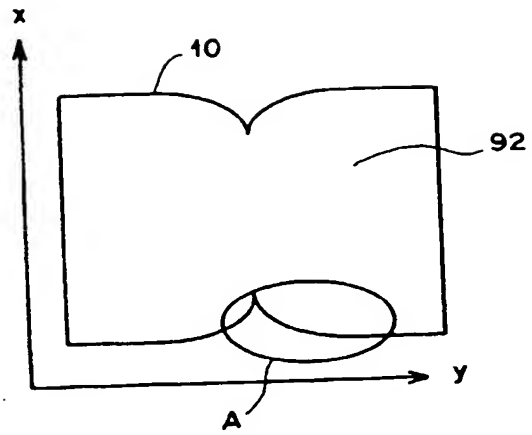

FIG.6b

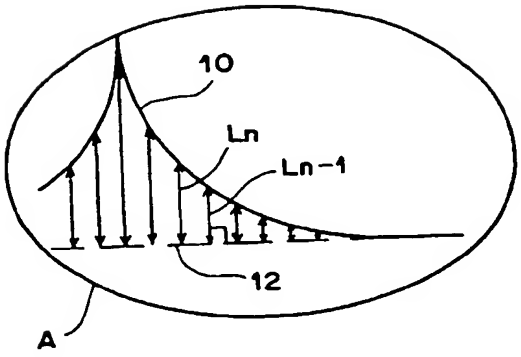

FIG. 9

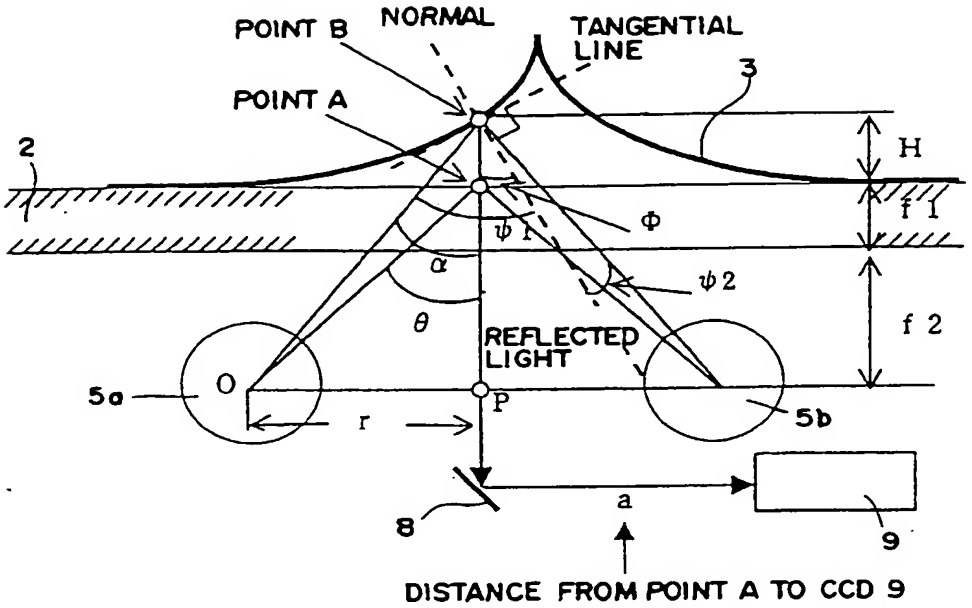

FIG. 10

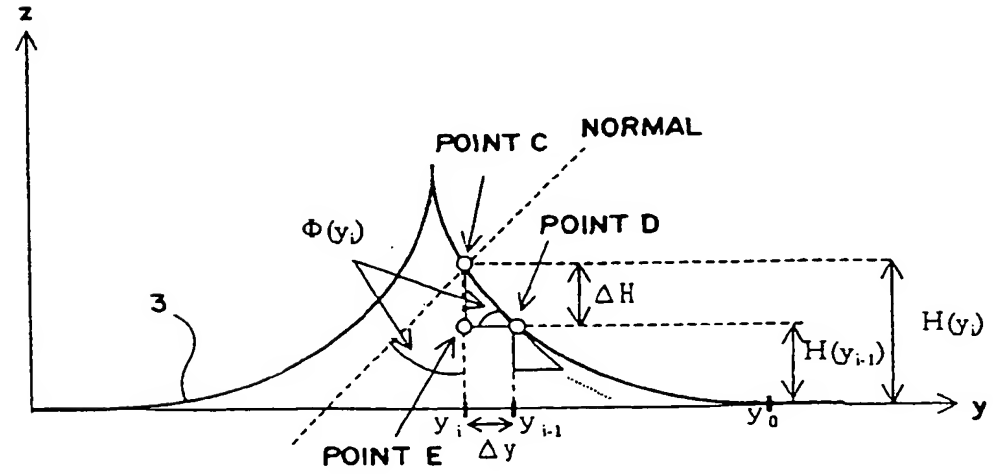

FIG.13

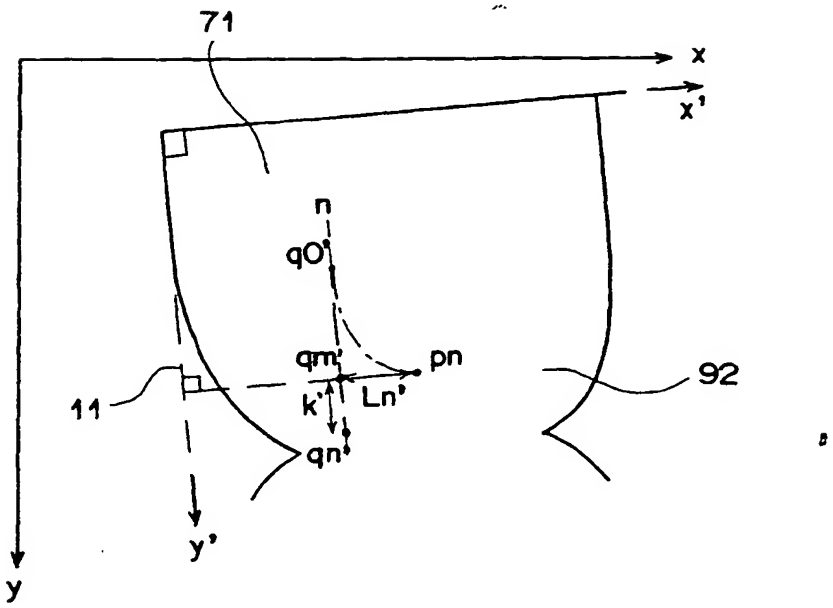

FIG.14